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Reduced Horizontal Separation Minima (RHSM) Concept Exploration Simulation

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16. Abstract

The Federal Aviation Administration (FAA) Air Traffic Requirements (ATR-310) and Air Traffic Operations (ATO-100) Program Offices tasked the Simulation and Systems Integration Branch (ACT-540) to explore the feasibility of implementing reduced oceanic separation minimums. A study identified as the Reduced Horizontal Separation Minima (RHSM) concept exploration simulation was conducted in the Oceanic Laboratory at the FAA William J. Hughes Technical Center. The study was designed to determine how many pairs of aircraft, longitudinally separated by 50 nm, could be managed by controllers in the Central Pacific airspace region. Specifically, the study was intended to assess the impact of reduced longitudinal separation on controller workload and to validate a suggested manual RHSM controller procedure. The procedure would require the pilots of the affected aircraft to report their positions from a common fix every 30 minutes. Based on this information, controllers would then calculate the separation distance. To be eligible for reduced separation, aircraft must be capable of Required Navigational Performance-10. Use of the Oceanic Data Link for communications was also required. Many trial runs of the RHSM were conducted. The activities of the controller team were video recorded. Oakland Air Route Traffic Control Center managers and FAA Headquarters personnel subsequently viewed the tape. An operational demonstration was also conducted by the controller team and witnessed by Oakland Air Route Traffic Control Center managers, FAA Headquarters personnel, and Japan Civil Aviation Bureau delegates. As a result of the observations and one-on-one feedback from the controllers, it was decided that the proposed process was too workload intensive for operational implementation.

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Executive Summary

The Informal South Pacific Air Traffic Services Coordinating Group has been investigating a number of concepts to improve operational efficiency for flights in the Pacific Oceanic region. The Federal Aviation Administration (FAA) Air Traffic Requirements (ATR-310) and Air Traffic Operations (ATO-100) program offices tasked the Simulation and Systems Integration Branch (ACT-540), in cooperation with the Oceanic and Offshore Integrated Product Team (AUA-600), to explore the feasibility of implementing reduced oceanic aircraft separations. These organizations formed an Experimental Working Group to make high-level decisions regarding the implementation of the proposed separation standard. In response, ACT-540 formed a Research Team to design and conduct a concept exploration study at the FAA William J. Hughes Technical Center. The Research Team led all efforts including the planning and design of the simulation and conduct of a simulation. The team also queried the controllers and compiled their responses regarding the proposed procedure.

This report discusses the Reduced Horizontal Separation Minima (RHSM) concept exploration simulation. In particular, the simulation was designed to explore issues that might affect a controller's ability to manage reduced longitudinal separation in the oceanic environment.

ATR-310 and ATO-100 personnel theorized that a procedural implementation of the 50/50 separation standard might be possible for the near term. The ACT-540 Research Team therefore designed the study to determine how many pairs of aircraft, longitudinally separated by 50 nm, could be managed by controllers in the Central Pacific airspace region. Because the study was intended to address only the controller's role, the Research Team did not address lateral separation issues. Traffic Management Unit personnel resolve lateral separation issues in Pacific Oceanic airspace.

Specifically, the Research Team designed the study to assess the impact of reduced longitudinal separation on controller workload and to examine a suggested manual RHSM controller procedure. The manual procedure would require the pilots of the affected aircraft to report their positions from a common fix every 30 minutes. Based on this information, controllers would then calculate the separation distance. To be eligible for reduced separation, aircraft must be capable of Required Navigation Performance-10 (RNP-10). Additionally, aircraft must be equipped with Controller/Pilot Data Link Communications (CPDLC) capabilities. For purposes of the simulation, all aircraft were RNP-10 and CPDLC equipped.

The Research Team completed preliminary activities for conducting the RHSM concept exploration simulation during August, September, and October 1996. These activities included

a. integration and test of the William J. Hughes Technical Center Oceanic Laboratory physical components,

b. exercise of the scenarios developed for data collection,

c. review and approval of the mechanisms used to extract subjective information, and

d. training of the individuals who would conduct and support the simulation.

Five Oakland Air Route Traffic Control Center (ARTCC) staff members participated in the preliminary process. A controller from the Oakland ARTCC International Office assisted in developing the scenarios and in validating the operational fidelity of the laboratory. Another controller individually exercised the scenarios over a 2-week period. A third controller independently exercised the scenarios for another 2-week period. Finally, a two-member team ran the scenarios for 2 weeks. During the process, the controller team developed a recording form to calculate separation distances.

On October 31, 1996, the Research Team video recorded the activities of the controller team. The tape was viewed by Oakland ARTCC managers and FAA Headquarters personnel on November 5, 1996. The following day, the controller team performed an operational demonstration of the procedure for Oakland ARTCC managers, the FAA Headquarters sponsors, and visiting Japanese Civil Aviation Bureau dignitaries.

On November 7, 1996, the controller team, Oakland ARTCC managers, FAA Headquarters sponsors, and the Research Team met to discuss the viability of the proposed manual RHSM process. They agreed that the proposed process, although having some utility in climb-through, descend-through, and very short term same-altitude situations, was too workload intensive to be used to sustain separation over long distances. The subjective data revealed that automation tools would be required to alleviate workload. They anticipated that additional simulations would be required to analyze the impact of separation reductions on controller workload when automation enhancements are in place.

1. Introduction

This report discusses the Reduced Horizontal Separation Minima (RHSM)[1] concept exploration simulation. It describes the simulation, procedures, and tools developed to ascertain the experiences of individuals who participated. The concept exploration examined issues that might affect a controller's ability to manage reduced longitudinal separation in the oceanic environment. A demonstration of the RHSM concept was conducted in the Oceanic Laboratory at the Federal Aviation Administration (FAA) William J. Hughes Technical Center on November 6 and 7, 1996.

2. Background

The Informal South Pacific Air Traffic Services Coordinating Group has been investigating a number of concepts to improve operational efficiency for flights in the Pacific Oceanic region. The FAA Air Traffic Requirements (ATR-310) and Air Traffic Operations (ATO-100) program offices tasked the Simulation and Systems Integration Branch (ACT-540), in cooperation with the Oceanic and Offshore Integrated Product Team (AUA-600), to explore the feasibility of implementing reduced oceanic aircraft separations. These organizations formed an Experimental Working Group (EWG) to make high-level decisions regarding the implementation of the proposed separation standard. In response, ACT-540 formed a Research Team to design and conduct a concept exploration study at the Technical Center. The Research Team led all efforts including the planning and design of the simulation and the conduct of a simulation. The team also queried the controllers and compiled their responses to the proposed procedure.

The study was conducted by the ACT-540 Research Team in the Oceanic Laboratory at the Technical Center. The purpose of this simulation was to assess the feasibility of a near-term procedural RHSM implementation for a 50-nm longitudinal reduction.

RTCA, a joint FAA/Industry committee, proposed that five separation reductions should be incrementally implemented over the near-, mid-, and long-term periods. Their proposed separations were

- 50 nm longitudinal - 50 nm lateral,
- 50 nm longitudinal - 30 nm lateral,
- 30 nm longitudinal - 30 nm lateral,
- 15 nm longitudinal - 15 nm lateral, and
- < 15 nm longitudinal - < 15 nm lateral.

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[1] Lateral separation is defined as the horizontal separation between tracks (e.g., wing-to-wing aircraft separation), and longitudinal separation is defined as the horizontal separation along the same track (e.g., nose-to-tail aircraft separation).

In the long term, use of Automatic Dependent Surveillance (ADS), Controller/Pilot Data Link Communications (CPDLC), and automated ground-based controller decision aids will provide the precision necessary to effectively monitor reduced aircraft separations.

Members of the ATR-310 and ATO-100 Program Office theorized that a procedural implementation of the 50/50-separation standard might be possible for the near term. They suggested a procedure that would require the pilots of the affected aircraft to report their positions from a common fix every 30 minutes. Based on this information, controllers would then manually calculate separation distances. Controllers would use Oceanic Data Link (ODL) for communications. To be eligible for reduced separation, aircraft must be capable of Required Navigation Performance-10 (RNP-10). Additionally, the aircraft must be equipped with CPDLC capabilities.

3. Simulation Overview

The Research Team designed the study to determine how many pairs of aircraft, longitudinally separated by 50 nm, could be managed by controllers in the Central Pacific (CENPAC) airspace region. Because the study was intended to address only the controller's role, the Research Team did not address lateral separation issues. Traffic Management Unit (TMU) personnel resolve lateral separation issues in Pacific Oceanic airspace. They establish lateral separation during the track development process according to the current separation standards. Calculation of lateral separation distances by sector controllers is not, therefore, required for aircraft solely operating on tracks developed by the TMU. Accordingly, the Research Team did not consider lateral separation to be a sector-controller workload issue.

3.1 Objective

The EWG established the RHSM simulation objective to determine the number of aircraft pairs that could be managed by controllers in the CENPAC airspace region if individual aircraft were longitudinally separated by not less than 50 nm.

Specifically, the EWG directed the Research Team to assess the impact of reduced longitudinal separation on controller workload and to validate the suggested manual RHSM controller procedure.

3.2 Constraints

The Research Team's design was constrained by the following factors:

a. A peak westbound flow of aircraft would be examined.

b. All westbound aircraft must operate on Pacific Organized Track System (PACOTS) tracks.

c. Lateral separation would not be addressed.

3.2.1 Assumptions

ATO-100 provided the draft interim procedure contained in Appendix A for use in the study. The Research Team made the following assumptions to reflect the principles contained in the procedure:

a. The minimum longitudinal separation distance between area navigation (RNAV)-equipped aircraft would be 50 nm.

b. Direct pilot to controller communication (DCPC) would be maintained while applying a 50 nm minimum (e.g., very high frequency voice or CPDLC).

4. Literature Review

The current oceanic air traffic control (ATC) system is characterized by poor communication systems, manual operations, and large separation standards (AOAS, 1997). The FAA estimates that air traffic over the Atlantic and Pacific oceans will double between 1996 and 2005 (Fee & Simpson, 1995). Existing airspace must accommodate the predicted increased air traffic. Although it is feasible to increase the number of runways and airports, it is not possible to increase the amount of airspace (O'Keefe, 1990). A possible solution is to reduce the separation minimums for oceanic air traffic. However, this option can not be realized without the technological implementations of data link and future air navigation systems (FANS).

Current limitations in the oceanic environment, in particular, communication, navigation, and surveillance (CNS) equipment, require the use of large separation standards that limit airspace capacity. The key to reducing delays and utilizing more efficient flight paths lies within reducing current separation standards. However, before separation can be reduced, significant improvements in communication and surveillance systems are necessary. Once improvements are made, reduced separation standards will be viewed as a viable way to optimize airspace while still maintaining safety standards (Fee & Feerrar, 1991; Joyce, 1990; Livingston, 1990).

During the next decade, in-trail separation distances are anticipated to be shortened from 10 to 15 minutes (80-120 nm) to 4 minutes (30 nm). It is also likely that the lateral separation distance on parallel tracks will be reduced from 100 nm to 30 nm (Fee & Simpson, 1995; Norris 1994). Separation minima for particular aircraft may vary, depending on the aircraft equipage (Fee & Feerrar, 1991).

RTCA has suggested that reduced separation standards should be progressively implemented using a five-step approach. As shown in the RTCA Implementation Model (Figure 1), separation is anticipated to be reduced from 50/50 nm to <15/<15 nm. Near-term implementation will require relatively small changes in existing facilities, equipment, and procedures. Over time, more significant changes will be required.

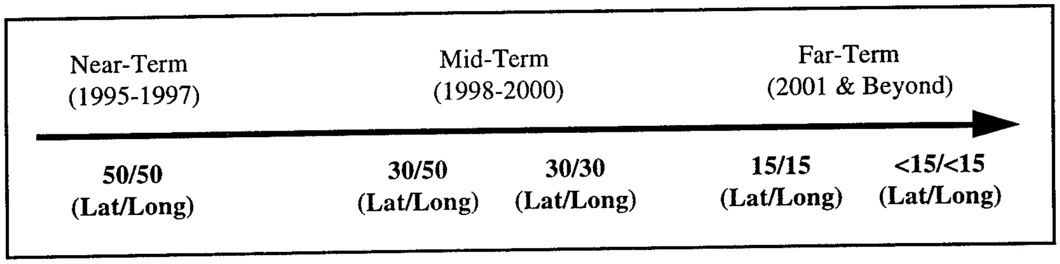

Figure 1. RTCA implementation model for oceanic separations.

To reach the goal of <15/<15 nm, CNS and automation capabilities must gradually improve. RTCA, therefore, recommended use of a flexible approach while designing systems and procedures in the near-term so that the mid- and long-term changes can be implemented as efficiently as possible (RTCA, 1995).

Closer separation standards will require development of new traffic monitoring displays and tools to assist in decision making for both the controller and pilot. To implement the proposed 50/50 nm separation, aircraft must be RNP-10 capable, and data link communications must be in place. As time progresses, more accurate controller displays indicating the time and location of the aircraft will be needed. Implementation of conflict probe and a decision support system is required to achieve mid-term goals (30/50 nm or 30/30 nm). ADS must be implemented for use in specific areas in the mid-term and fully implemented to meet long-term communications objectives (RTCA, 1995).

The nature of pilot-controller interactions must be addressed as reduced separation standards evolve. As free flight initiatives are implemented, it is likely that more separation responsibilities will transfer from the controller to the pilot. To accommodate this philosophical change, associated liability issues must be resolved (RTCA, 1995).

As separation reductions proceed, an increase in benefits associated with RHSM is predicted. It is expected that improved aircraft systems, such as FANS, will reduce airspace requirements to less than 1/16 of the current requirements (Norris, 1994). The resultant increase in airspace capacity is anticipated to accommodate the forecasted air traffic increase for the next decade. When coupled with user-preferred routes, RHSM implementation is expected to reduce air miles with consequent fuel, time, and flight crew cost savings (Fee & Feerrar, 1991; RTCA, 1995).

Studies should be conducted to ensure that the proposed separation reductions will not increase hazards or risks or cause operator or traveler discomfort. The FAA must demonstrate that the proposed separation reductions will be economical, efficient, and safe (RTCA, 1995).

5. Experimental Design and Approach

6. Airspace

The Research Team designed the simulation to reflect the operational conditions resident in the field in July 1996. According to agreements with the International Civil Aviation Organization

(ICAO), Oakland Air Route Traffic Control Center (ARTCC) is responsible for ATC in the Oakland Flight Information Region (FIR). Figure 2 depicts the Oakland FIR sector configuration for July 1996. The Research Team selected Oakland Oceanic Sector (OC)7 for the simulation.

Geographically, OC7 is located between 127° and 150° west longitude and between 35° and 47° north latitude. Operationally, westbound traffic is transferred into OC7 from the domestic sectors or OC2 and is subsequently transferred into either OC2 or OC4. Eastbound traffic enters OC7 from OC2 or OC4 and is then transferred into OC2 or the domestic sectors. OC7 has no radar coverage.

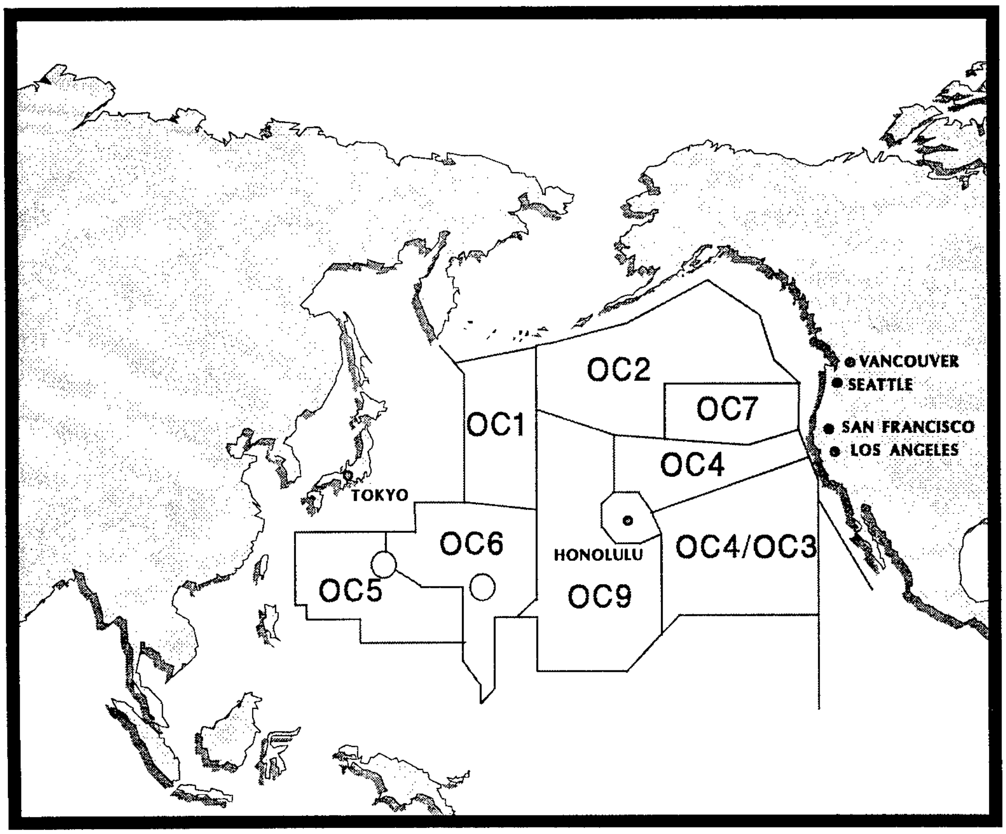

Figure 2. Oakland Flight Information Region.

6.1 Track Description

The Research Team incorporated PACOTS tracks Delta (D), Echo (E), and Foxtrot (F), into the design. These tracks matched those generated by Oakland TMU on July 1, 1996. The tracks are depicted in Figure 3.

By convention, westbound PACOTS tracks are generally alphabetically labeled and eastbound tracks are identified with a number. Detailed information associated with the tracks is provided in Appendix B.

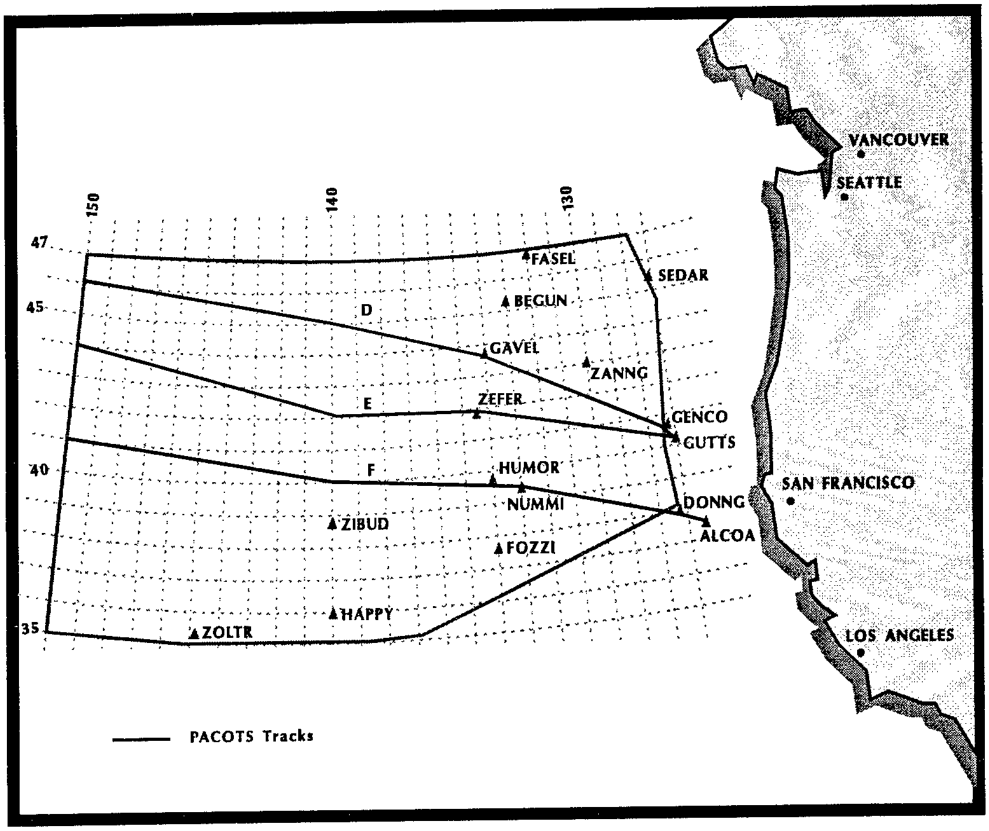

Figure 3. OC7 configuration.

6.2 Scenarios

The Research Team developed four scenarios for the study. These included one for training (TR) and three for data collection purposes (1R, 2R, and 3R). Scenarios 1R and 2R each included 10 opportunities for aircraft to be separated by less than the current longitudinal separation standard. Scenario 3R was planned as the baseline scenario (which represents current separation standards for comparison purposes) and did not contain reduced separation opportunities. Four separation opportunities were contained in Scenario TR. A summary of the characteristics of each scenario is provided in Table 1.

All aircraft on tracks D, E, and F were westbound. In Scenarios 1R, 2R, and 3R, four overflight[2] aircraft were eastbound, one was southwestbound and one was northeastbound. In the TR scenario, one overflight aircraft was eastbound, and one was southwestbound.

[2] The term overflight, as used in this report, means aircraft that are not flying PACOTS tracks D, E, and F.

Table 1. Scenario Characteristics

ID	Scenario Duration	Use	Aircraft in Scenario	Overflight Aircraft	Aircraft on Track D	Potential Track D RHSM Pairs	Aircraft on Track E	Potential Track E RHSM Pairs	Aircraft on Track F	Potential Track F RHSM Pairs	Total Potential RHSM Pairs
TR	90 Minutes	Training	20	2	6	2	6	0	6	2	4
1R	150 Minutes	Data Collection	39	6	11	4	11	2	11	4	10
2R	150 Minutes	Data Collection	39	6	11	2	11	4	11	4	10
3R	150 Minutes	Data Collection	39	6	11	0	11	0	11	0	0

6.3 Traffic

The Research Team used a traffic mix that was based on a 3-hour snapshot of the Oakland ARTCC traffic flown on May 31, 1996. Because the objective was to measure workload effects and not separation skills, the team organized the aircraft positions in a fashion that ensured that conflicts would not occur. At least a 50-nm separation was always maintained between aircraft. The team used different aircraft call signs and altitude assignments between scenarios to reduce learning effects.

Scenarios 1R, 2R, and 3R each incorporated 33 aircraft operating on tracks D, E, and F. These aircraft departed San Francisco International Airport (KSFO), Los Angeles International Airport (KLAX), Seattle International Airport (KSEA), San Jose International Airport (KSJC), and Vancouver International Airport (CYVR). Destinations included Tokyo - Narita International Airport (RJAA), Osaka - Kansai International Airport (RJBB), Seoul - Kimpo International Airport (RKSS), Taipei - Chinag Kai Shek International Airport (RCTP) and Hong Kong - Kaitek International Airport (VHHH).

Scenarios 1R, 2R, and 3R also included six overflight aircraft that crossed tracks D, E, and F. These included two aircraft from the far east to KSFO, two from the far east to KLAX, one from Honolulu International Airport (PHNL) to KSEA, and one from KSEA to PHNL.

The training scenario included 18 aircraft operating on tracks D, E, and F. Although fewer aircraft were included, the origins and destinations were identical to those contained in Scenarios 1R, 2R, and 3R. The TR scenario included two overflight aircraft that crossed tracks D, E, and F, one from the Far East to KLAX and one from CYVR to PHNL. Detailed traffic characteristics are shown in Table 2.

Table 2. Traffic Characteristics

	Scenarios 1R, 2R, and 3R			Scenario TR		
	Number and Type Aircraft	Departure Points	Destinations	Number and Type Aircraft	Departure Points	Destinations
Westbound Traffic	18 B747-400 11 B747 3 MD11 1 DC10	KSFO KLAX KSEA KSJC CYVR	RJAA RJBB RKSS RCTP VHHH	11 B747-400 7 B747	KSFO KLAX KSEA KSJC CYVR	RJAA RJBB RKSS RCTP VHHH
Crossing Traffic	4 B747-400 1 DC10 1 CL60	RCTP PHNL CYVR	KSFO KLAX KSEA PHNL	1 B747-400 1 CL60	RCTP CYVR	KSFO KLAX PHNL

6.4 Participants

Five Oakland ARTCC staff members participated in the preliminary process. They exercised the scenarios several times. A controller (A) from the Oakland ARTCC International Office assisted in developing the scenarios and in validating the laboratory operational fidelity. Another controller (B) individually exercised the scenarios over a 2-week period. A third controller (C) independently exercised the scenarios for another 2-week period. Finally, a two-member team (D and E) ran the scenarios for 2 weeks and for the simulation. Each controller that was involved in exercising the scenarios or participating in the simulation was a Full Performance Level controller, sector certified and ODL trained.

6.5 Experimental Procedure

Before running the scenarios, a member of the Research Team briefed the controllers regarding their roles, the simulation objectives, and the procedures for reducing and sustaining the required separation. During the briefing, the controllers were provided with a recording form to be used to manually calculate the separation distances. This form was developed by the team in collaboration with Oakland ARTCC controllers. A copy of the form is provided in Appendix C. All scenarios were exercised several times.

The Research Team debriefed the participants upon the completion of each run. Following the simulation, the team met with the controllers to discuss the viability of the RHSM procedure. At the end of the meeting, controllers D and E completed the Post-Run and Post-Simulation Questionnaires. A third controller, C, who helped test the scenarios before the simulation, completed Post-Run and Post-Simulation Questionnaires after the simulation (see Appendix D).

6.6 Simulation Technical Staff

The personnel who helped support the simulation in the Oceanic Laboratory were defined as the simulation technical staff. Two technical staff members performed Assistant Controller functions (e.g., passing Flight Progress Strips to the controller team as the scenarios progressed). A third, with controller experience, performed the ground-to-ground communication functions of adjacent sectors. This individual interacted with the controller team to transfer[3] aircraft entering OC7 using emulated ground-to-ground communications equipment. An additional member performed air-to-ground communications. At appropriate times, this person originated pre-formatted data link messages to the controller team using the Oceanic Laboratory Oceanic Development Facility (ODF) equipment. This individual also responded to ground-to-air messages originated by the controller team.

Additional technical staff members were available to load new scenarios and trouble shoot technical problems that occurred. The Research Team, consisting of a Test Director and staff, facilitated the simulation.

6.7 Configuration Management

According to the requirements provided by the Research Team, an environment similar to Oakland ARTCC OC7 was emulated in the William J. Hughes Technical Center Oceanic Laboratory. An overview of the Oceanic Laboratory layout, as configured, is shown in Figure 4.

The laboratory contained an ODF, a Target Generator (TG), a Telecommunications Processor (TP), an Oceanic Display and Planning System (ODAPS) version 1.0, a Remote Operator (RO) station, and an ATC workstation. The ATC work station consisted of a Plan View Display (PVD) console, an ODL terminal, a printer, fixed and portable strip bays, a voice communications suite, and an overhead map case containing a chart that displayed the PACOTS tracks. Portable strip bays were used due to capacity limitations associated with the laboratory fixed strip bays.

6.7.1 Hardware and Software Configuration

The TG provided flight progress reports that represented the trajectory of simulated aircraft. The ODF TG utilizes flight plan and adaptation data to generate simulated aircraft targets. The TG allows the simulated aircraft to dynamically react to controller-issued clearances. One Digital Equipment Corporation workstation was configured as an RO workstation. The RO workstation allows the flight plan data resident in the TG to be modified.

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[3] Transfer is the term used by Oakland ARTCC oceanic controllers to describe the activities associated with the transfer of controller responsibilities between sectors for an aircraft.

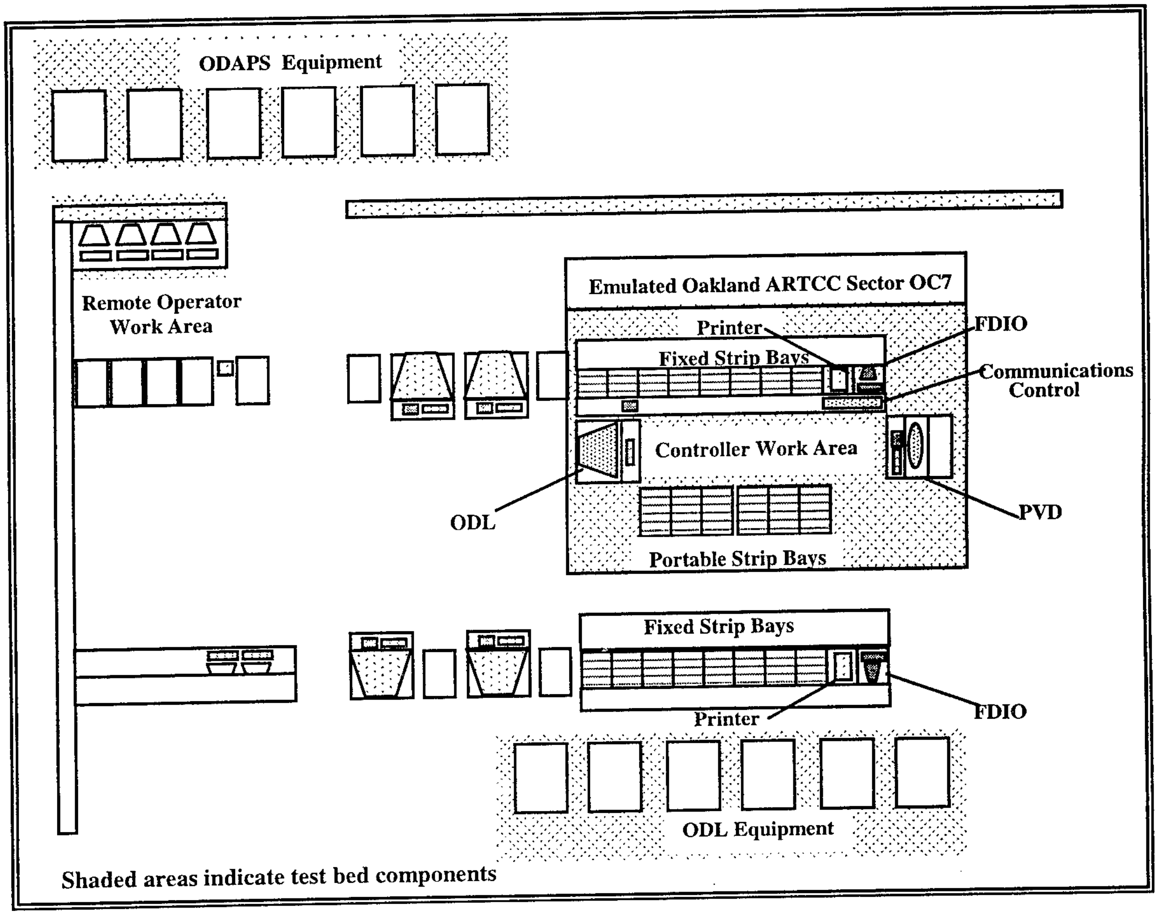

Figure 4. William J. Hughes Technical Center Oceanic Laboratory.

The ODAPS was configured to simulate OC7 using stored adaptation data. The ODAPS processes flight plan data and related messages to produce outputs for transmission via a TP control unit to the ODL terminal. The ODL terminal is located in the controller work area. The ODL handles all data link communications and ODAPS interactions. The ODAPS provides a graphical representation of extrapolated flight plan positions on the PVD for the controllers.

ODAPS laboratory technicians used the system build restore tape numbered A10052 to incorporate the Oakland ARTCC adaptation. They loaded software version SA2030 on the Oceanic Display Channel and software version SA0050 on the Oceanic Communication System. ODL technicians used software version 1.0 to emulate the Oakland ARTCC ODL configuration.

6.7.2 Voice Communications System

ACT-540 technical staff provided a Robert Thomas Smith (RTS) Systems Model CS9500 Digital Intercom System to satisfy the ground-to-ground communications functions between the emulated adjacent sectors and the controllers. Each controller was given a 16-channel key panel unit that provides communication functionality similar to that found on the floor of the ARTCC, exclusive of a shout line.

The RTS CS9500 is a portable, programmable intercommunication system that maintains high quality speech characteristics utilizing a four-wire, central, non-blocking matrix design. Programming was provided by an MS-DOS-based package (CSEdit) operating on a 486 laptop personal computer connected to the matrix through a serial communication port.

6.7.3 Audio and Video Recording

An extensive audio and video system was installed by members of the ACT-540 technical staff for use during data collection. A low-light, micro camera was used to record controller interactions within the sector. A second micro camera was used to record the information displayed on the PVD. A scan converter was used to convert the information on the ODL display to a video format for recording on a third videotape. All video was recorded in Super VHS format on 2-hour tapes stamped with National Television System Committee linear time code for synchronous playback purposes.

Three separate audio signals were recorded, two from the wireless microphones worn by each controller and one directly from the RTS CS9500 system used by the RO. The audio signals were mixed according to the corresponding camera views using a Tascam M2516 audio mixing board and recorded on the hi-fi audio channels of the videotapes.

7. Data Collection

The C, D and E controllers completed Post-Run and Post-Simulation Questionnaires after the simulation. The Post-Run Questionnaire elicited run-specific responses regarding overall workload, workload variation, traffic load, busyness in the run, flight strip management, controller activities, utility of the RHSM procedure, and safety of the RHSM process. The Post-Simulation Questionnaire elicited responses on ODL features and computer-human interface, utility of the RHSM procedure, safety of the RHSM process, controller strategies, and opinions regarding other equipment.

7.1 Data Analysis

The Research Team grouped and analyzed the subjective comments obtained from both the Post-Run and Post-Simulation questionnaires. The results are described in the following section. Responses to the questionnaires are provided in Appendix D.

8. Results

The Research Team, the controller participants, and the technical staff conducted extensive preliminary activities from August through October 1996. These included integration and test of the physical components of the Oceanic Laboratory, exercise of the scenarios developed for data collection, review, and approval of the questionnaires used to record subjective information, and the training of the individuals who conducted and supported the simulation. During the process, the controllers and the Research Team developed a recording form for manually calculating separation distances. A copy of the form is provided in Appendix C.

On October 31, 1996, the activities of the controller team were video recorded by the Research Team. Oakland ARTCC managers and FAA Headquarters personnel viewed the tape on November 5, 1996. On November 6, 1996, the controller team performed an operational demonstration for Oakland ARTCC managers, FAA Headquarters sponsors, and visiting Japanese Civil Aviation Bureau (JCAB) dignitaries.

As a result of the experience gained while establishing and validating the simulation methodology, associated scenarios, and apparatus, it became evident that the proposed manual process was too workload intensive to maintain aircraft separation for an extended period of time without improved automation capabilities.

9. Conclusions

On November 7, 1996, a meeting was held with the controller team, Oakland ARTCC managers, FAA Headquarters sponsors, and the Research Team to discuss the viability of the proposed manual RHSM process. They agreed that the proposed process, although having some utility in climb-through, descend-through, and very short-term same-altitude situations, was too workload intensive to be used to sustain reduced separation over long distances. The subjective data revealed that automation tools would be required to alleviate workload. FAA Headquarters sponsors decided that the proposed manual procedure would not be operationally implemented. It was agreed that additional simulations would be required to analyze the impact of separation reductions on controller workload when automation enhancements are in place.

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Acronyms

ADS	Automatic Dependent Surveillance
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
CENPAC	Central Pacific Region
CNS	Communication, Navigation, and Surveillance
CPDLC	Controller/Pilot Data Link Communications
CYVR	Vancouver International Airport
DCPC	Direct Pilot to Controller Communication
EWG	Experimental Working Group
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FIR	Flight Information Region
ICAO	International Civil Aviation Organization
JCAB	Japanese Civil Aviation Bureau
KLAX	Los Angeles International Airport
KSEA	Seattle International Airport
KSFO	San Francisco International Airport
KSJC	San Jose International Airport
ODAPS	Oceanic Display and Planning System
ODF	Oceanic Development Facility
ODL	Oceanic Data Link
PACOTS	Pacific Organized Track System
PHNL	Honolulu International Airport
PVD	Plan View Display
RCTP	Taipei - Chinag Kai Shek International Airport
RJAA	Tokyo - Narita International Airport
RJBB	Osaka - Kansai International Airport
RKSS	Seoul - Kimpo International Airport
RHSM	Reduced Horizontal Separation Minima
RNAV	Area Navigation
RNP	Required Navigation Performance
RO	Remote Operator
RTS	Robert Thomas Smith
TG	Target Generator
TMU	Traffic Management Unit
TP	Telecommunications Processor
VHHH	Hong Kong - Kaitek International Airport

Appendix A

Draft RHSM Procedures

DRAFT

LONGITUDINAL DISTANCE SEPARATION

PROCEDURES

Section 9. PACIFIC ICAO REGION

8.9.4. LONGITUDINAL SEPARATION DISTANCE

a. The minimum longitudinal separation distance between RNAV-equipped aircraft, approved to RNP-10 or better, shall be 50 NM derived by RNAV.

b. This minima is applicable to such aircraft cruising, climbing, or descending on the same track and is also applicable between such aircraft on reciprocal tracks providing the aircraft have passed one another.

1. DCPC shall be maintained while applying a 50 NM RNAV minimum, e.g., DCPC shall be voice or CPDLC.

2. Separation shall be established by maintaining not less than the 50 NM RNAV separation minimum between aircraft positions as reported by reference to the same "on track" waypoint, whenever possible ahead of both aircraft, or by means of an automated reporting system, e.g., ADS.

3. Distance verification shall be obtained from each aircraft pair at least every 30 minutes to verify that separation is maintained; and

4. If an aircraft fails to report distance information within 38 minutes from the last reporting time, action shall be initiated to establish an alternate form of separation.

5. If separation is determined to be less than 50 NM RNAV at the time distance is reported, action shall be initiated to establish 50 NM *or* to apply an alternate form of separation prior to the next distance reporting time.

CPDLC APPLICATION

Controllers shall request distance information from both aircraft by sending a CPDLC message with appropriate free text information appended as follows:

REPORT DISTANCE [to/from] [position]

At [time]

Optional: [and every x minutes thereafter][4]

Pilots will respond with a CPDLC message as follows:

AT [time] [distance] [to] [from] [position]

NOTE- When the pilot receives a CPDLC message requesting distance information appended with time instructions, they will send the message at the time specified.

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[4] The pilot would then resend distance from that fix at the specified time interval.

Appendix B

Detailed Track Information

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WESTBOUND PACOTS FOR RHSM

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WESTBOUND NORTH AMERICA - JAPAN PACOTS

FL280 AND ABOVE

TRACK D		
	FLEX ROUTE:	GUTTS GENCO GAVEL 45N/140W 46N/150W 44N/170W 42N/180E 40N/170E 39N/160E GARRY
TRACK E		
	FLEX ROUTE:	GUTTS ZEFER 42N/140W 44N/150W 43N/160 W 42N/170W 38N/180E 36N/170E 35N/160E MILVA
TRACK F		
	FLEX ROUTE:	ALCOA DONNG NUMMI 40N/140W 41N/150W 40N/160W 39N/170W 38N/180E 36N/170E 35N/160EMILVAAppendix C

Appendix C

RHMS Distance Form

RHSM Distance Calculation

Fix					
Following A/C Callsign					
Leading A/C Callsign					

Appendix D

Controller Comments

CONTROLLER RESULTS

POST-RUN QUESTIONNAIRE

Question 1.	Controller A	Controller B	Controller C
How does the traffic load of this run compare to typical Sector OC7 traffic? [Very Light (1) to Very High (7)]	4	5	3

Question 2.	Controller A	Controller B	Controller C
How do you compare the simulated flight deck response times with those experienced in the real world? [Very Slow (1) to Very Quick (7)]	7	7	4

Question 3.	Controller A	Controller B	Controller C
Circle the number which best describes your workload level during this run? [Very Low (1) to Very High (7)]	4	4	4

Question 4.	Controller A	Controller B	Controller C
Was the workload uniform throughout this run? (Yes=Y, No=N)	Y	N	N

Question 4.a

If your response is NO, describe how it fluctuated and whether such a variation is normal in Sector OC7.

Response	
Controller A	
Controller B	Normal variation for OC7.
Controller C	Increasing workload as more aircraft were brought into sector. Also some transitions to next sector.

Question 5.	Controller		
	A	B	C
How busy were you during this run? [Not Busy at All (1) to Extremely Busy (7)]	4	4	5

Question 5.a	
What activities contributed to your busyness?	
Response	
Controller A	Requests, position reports, monitoring the RHSM pairs.
Controller B	Bringing up the RHSM messages on ODL and typing in all the information and keeping track of the 30 min. reports, doing the math to see how far the aircraft were apart.
Controller C	Trying to control traffic, responding to requests and shaking down the system.

Question 6.	Controller		
	A	B	C
How much thinking and planning were required during this run? [Minimal thinking & planning (1) to Great deal of thinking & planning (7)]	4	6	2

Question 6.a	
List activities that caused thinking and planning.	
Response	
Controller A	Possible climbs, maintaining separation
Controller B	What fix was common to both aircraft, what time to use to report that point, who could RHSM be used with.
Controller C	

Question 7.	Controller		
	A	B	C
How would you rate the flight strip management of this run? [Could very easily keep up strip marking (1) to Could not keep up strip marking at all (7)]	2	4	3

Question 7.a	
How could this process be automated/improved/aided?	
Response	
Controller A	We ran it as a two man sector. If it was just one, it would have been too time-consuming.
Controller B	We developed a strip for a second controller to keep track of the paired RHSM aircraft. This helped but the entire operation should be automated i.e., the aircraft should tell the controller how far apart they are.
Controller C	Electronic strips.

Question 8.	Controller		
	A	B	C
Were all the RHSM requests approved during this run? (Yes=Y, No=N)	N	Y	N

Question 8.a	
If your response is NO, explain the circumstances for not approving the RHSM eligible "climb" or "descend" requests.	
Response	
Controller A	Some required some time before the appropriation separation could be achieved.
Controller B	
Controller C	I recall one instance that I had to consider 15^0 divergence and apply Mach so I could climb the aircraft through the altitude to the requested flight levels.

Question 9	Controller		
	A	B	C
Did you have any difficulty with the ODL computer-human interface or the message composition when implementing RHSM? (Yes=Y, No=N)	N	Y	Y

Question 9.a	
If your response is YES, explain in detail.	
Response	
Controller A	
Controller B	Too much typing.
Controller C	This I explained in the other questionnaire.

Question 10.	Controller		
	A	B	C
How manageable was the RHSM process? (Manageable=M, Unmanageable=U)	U	U	Mostly M

Question 10.a	
If your response is Unmanageable, how could the RHSM process be made manageable?	
Response	
Controller A	Unmanageable for one person recording all the time/distances for each flight.
Controller B	One or two if no other traffic.
Controller C	In small amounts.

Question 11.	
Describe how you divided the control, strip marking, and communication activities of this run between the primary and assistant controller.	
Response	
Controller A	The primary controller handles messages and relays the distances to the assistant who records. The primary is responsible for separation but receives input from the assistant.
Controller B	Primary controller runs the strips and the second controller runs the PVD, RHSM strip, and other assigned duties (i.e., temp/modes).
Controller C	Not applicable (single control operation).

Question 12.	Controller		
	A	B	C
Did the application of the RHSM procedure distract from your operational priorities? (Yes=Y, No=N)	Y	Y	Y

Question 12.a	
If your response is YES, explain in detail.	
Response	
Controller A	It takes a great deal of time and attention.
Controller B	The procedure of asking aircraft every 30 minutes for distance reports is unworkable. It takes too much time to monitor the aircraft.
Controller C	A great deal of added workload to satisfy one aircraft. The procedure lacks simplicity. It takes only ten minutes just to set it up and then must be monitored at least every 30 minutes in addition to normal progress reports. Very time consuming.

Question 13.	
Identify what contributed to your workload.	
Response	
Controller A	Making sure to get the reports needed, recorded, and verified for appropriate separation.
Controller B	Formulating the clearances on the ODL you have to type too much information in free text. You have to process a lot of information as you type (i.e., latitude, longitude, times, and callsigns).
Controller C	This and Question 14 were discussed in the other questionnaire.

Question 14.	
What processes/systems could decrease the workload?	
Response	
Controller A	Some type of automated reports.
Controller B	The distance information must come in automatically and be the distance between the two aircraft not the distance from a point.
Controller C	

Question 15.	
Provide any additional comments or concerns about the RHSM process as experienced in this run.	
Response	
Controller A	It may be a procedure that will be useful under ADS; right now it's too tedious and will have little practical value in the field.
Controller B	RHSM for longitudinal separation is not useful in its present form. We need to look at reduced lateral separation (i.e., 50 mile lateral).
Controller C	

CONTROLLERS RESULTS - POST - SIMULATION QUESTIONNAIRE

Reduced Horizontal Separation Minima (RHSM)

Question 1.	**Controller A**	**Controller B**	**Controller C**
Did the features available in the ODL system adequately support the communication interactions required to efficiently execute the RHSM process? [Completely Inadequate (1) to Completely Adequate (7)]	5	2	

Question 1.a	
What modifications, if any, may be useful for efficient execution of the RHSM process (using two-way data link only)?	
	Response
Controller A	Need Better Pre-Composed Messages.
Controller B	We need to be able to recall messages with the ODL. It is too slow and inaccurate to type all the needed information every 30 minutes.
Controller C	With reference to question 1, I do not believe that the data link efficiently handles communication for the RHSM process because I recall that we had to use two function keys and add to that a free text message just to ask for the information at 30 minute intervals. At this time I cannot recall what the formatted messages were but I recall the free-text was the effect of "…. at __ minutes past the hour then at 30 minute intervals". This had to be done for each aircraft. The entire process was very labor intensive and benefited only the aircraft requesting the desired altitude. Why the aircraft who was already at the desired altitude would want to get into 30 minute reports in addition to normal position reports is a mystery to me. Also, why the controller would want to get into this type of separation with the great increase in workload also needs to be answered. It may be useful for climbing through an altitude or for very short term same altitude use but for long term en route separation it simply requires too much concentration. As to the ODL modification, the entire request should be on one function key and should be able to be sent to both aircraft at the same time so you don't have to do the same message twice.

Question 2.	**Controller A**	**Controller B**	**Controller C**
Was there sufficient information displayed on the ODL to support the RHSM communication tasks? [Insufficient (1) to Completely Sufficient (7)]	5	2	

Question 3.	Controller		
	A	B	C
Was there any excess information displayed on the ODL that interfered with the RHSM communication tasks? (Yes = Y, No = N)	N	Y	

Question 3.a	
If Yes, identify the excess information.	
Response	
Controller A	
Controller B	To get the RHSM message you have to "click" through too many buttons with labels that have nothing to do with RHSM.
Controller C	It's been too long since we did this for me to recall adequately what was displayed and to answer these questions. I do recall that we had all the information that we needed to do the simulation but what may have been excess or what else should have been displayed escapes me. My thoughts at the time were that this worked in the perfect simulation world but I didn't believe that the required reports would come on such a timely basis in real control. Pilots are human and many times requested reports don't come at the time requested and in the format needed for control. Sometimes they don't come at all and it concerns me just how much additional workload this is going to place on the controller.

Question 4.	
What additional information, if any, should be displayed?	
Response	
Controller A	None.
Controller B	You need a button labeled "RHSM" which would have all the information necessary for the controller to quickly fill in the blanks and then be recalled with a call sign change by the next aircraft.
Controller C	

Question 5.	Controller		
	A	B	C
Did the design of the computer-human interface (CHI) allow for the efficient completion of RHSM tasks? [Poor Design (1) to Excellent Design (7)]	5	2	

Question 5.a	
Describe how the CHI could be modified to improve the ODL for use in the RHSM application.	
Response	
Controller A	No suggestion.
Controller B	See number 4.
Controller C	Are you asking about the keyboard or ODL in general? Maybe you're asking about something else entirely. To me, the computer human interface is ODL and to that end I would have to say that the system is mediocre at best. It is not because it didn't try to be a good system. I think the engineers truly attempted and are still trying to give us a very usable system. My problem with it is that it is too labor intensive and requires me to do too much on the keyboard. Because of this my attention is diverted almost entirely to the ODL CRT and its constant need for proper formatting and away from what I get paid to do which is control and separate airplanes. There is simply too much to do and too many options always on display. There are probably less than 20 clearances, requests or advisories that I give on a daily basis. What I have available is more than I want and certainly more than I will ever need. What I do use, however takes too many keystrokes and requires the use of the mouse at times because there is no key available to get to certain features. Many times you have to go to the keyboard then mouse then keyboard again. I could go on for a long time in this area and comment in great detail about what I would do to make the system better but suffice to say that answer to your question is that the CHI needs improvement. As to RHSM, I again say, put the request to both aircraft on one key and send it to both aircraft at the same time. Something like this format: ATC request [A/C 1] [A/C 2] forward DME distance from [fix] at [time] and every [xx] minutes thereafter. The completed message would read: ATC request UAL853/NWA27 forward DME distance from 150W at 2145Z and every 30 minutes thereafter. The message that would be sent and received in the cockpit would indicate only the aircraft that it was intended for.

Question 6.	
In general, how many RHSM pairs can be managed safely and why?	
Response	
Controller A	By one controller in busy times, one or two. By two controllers or one controller in a quiet sector, unlimited.
Controller B	If the system were set up with Recall, and RHSM message, a 30 minute alarm timer, built in calculator, and no other traffic you could run 3 or 4 pairs.
Controller C	This is a tough question as it depends on many factors. Quantity of traffic, complexity, expected traffic, usable equipment, etc. At times, the answer will be that zero pairs of RHSM aircraft can be handled safely. As to the upper end, I don't think that there is an accurate answer and cannot give you any certainty. Personally, from what I saw, I don't think that I would want to do more than 4 or 5 pairs at any given time and would probably feel most comfortable working two or three pairs. This would be based on moderate traffic without a great deal of complexity and is my answer with having only done it a few minutes. As experience with it is gained, and it's use becomes routine, then my upper limit would also change.

Question 7.	Controller		
	A	**B**	**C**
How manageable was the RHSM process? (Manageable = M, Unmanageable = U)	U	U	M in small doses

Question 7.a	
If your response is unmanageable, how could the RHSM process be made manageable?	
Response	
Controller A	With ADS or some type of integration system that automatically records plane's positions.
Controller B	Having aircraft give position reports every 30 minutes makes it very hard to manage. If we were fully automated this might work. But for now the controller does not have a reliable way of monitoring the aircraft's 30 minute reports. We use strips which are 50 to 100 minutes apart.
Controller C	

Question 8.	Controller		
	A	B	C
Did you use any new control strategies/techniques or modify existing control strategies/techniques in any way while implementing the RHSM process? (Yes = Y, No = N)	Y	Y	Y

Question 8.a	
If your answer is YES, then explain.	
Response	
Controller A	We had new strips devised to record flight distances by time with a column on bottom to keep track of differences between the two flights.
Controller B	We used an extra strip which helped keep track of the pairs.
Controller C	This was discussed at Atlantic City and dealt mostly with strip marking.

Question 9.	Controller		
	A	B	C
Based on your experience with the RHSM process, do you recommend any changes in the procedures or equipment? (Yes = Y, No = N)	Y	Y	Y

Question 9.a	
If your answer is YES, then describe what procedures or equipment should be utilized to make the RHSM process more efficient, effective, and safe.	
Response	
Controller A	Right now its very tedious and not very useful. Generally aircraft will either be too close or far enough to mach. As set up now it requires a lot of time to initiate and continue to separate.
Controller B	Automate the entire process.
Controller C	Again, this has been discussed in Atlantic City and add to that what I have already written here.

Question 10.	
Provide any suggestions or comments about how the control, communication, and strip marking activities associated with the RHSM process can be effectively and efficiently divided between the primary and assistant controllers.	
Response	
Controller A	The primary controller handles the messages and makes sure the assistant controller records the distances. The assistant controller can keep track of increasing/decreasing separation.
Controller B	The assistant controller was in charge of the RHSM strip. On this strip he would keep track of the aircraft ID, fix distance and the difference in miles between the two or three aircraft.
Controller C	Previously discussed in Atlantic City. Since I only worked by myself at the Tech Center I am not fully sure of how to answer this. My feeling is that one controller [ATC1] should be working the traffic that is actively inside the sector and the other [ATC2] should be taking and giving hand-offs. ATC1 would determine RHSM pairs and set up separation. ATC2 would assist in this as needed. ATC2 would coordinate with the next sector and ensure that all required information was passed for continued RHSM use. He could also set it up if coming from the previous nonradar or radar sector.

Question 11.	
Identify what contributed to your workload.	
Response	
Controller A	The lengthy message to set up the pair. Then the wait for the reports and the continual workload of getting frequent reports.
Controller B	1. Formatting the messages in ODL. 2. Monitoring the times for all the different pairs of aircraft related to when they should report. 3. Strip marking the RHSM strips.
Controller C	Quantity of traffic, complexity and requests. No surprises here.

Question 12.	
What processes/systems could decrease the workload?	
Response	
Controller A	With ADS or some type of integration system that automatically records plane's positions.
Controller B	Automate the aircraft so they would monitor the distance from the other aircraft.
Controller C	Less traffic, lack of complexity and no requests.

Question 13.	
What features could be automated to help reduce workload?	
Response	
Controller A	With ADS or some type of integration system that automatically records plane's positions.
Controller B	The distance measuring equipment on the aircraft to tell/keep track of the distance between aircraft.
Controller C	There is no guarantee that automation will reduce workload. With the exception of bookkeeping tasks and the addition of the ODAPS PVD I have yet to see where automation has decreased our workload. Actually, all it has done is increase it. ODL doe not decrease the load, RHSM will not decrease our load. The only way that our workload would be decreased with ODL is if we went to electronic strips that updated as we used the ODL system. Until that comes to pass, our workload does not decrease and many times increases. Please understand that I am all for a certain amount of automation but don't believe for one minute that automation is the savior of oceanic ATC. Remember how computers were going to make this a paperless society?

Question 14.	
Provide any additional comments or concerns about the RHSM process.	
Response	
Controller A	I feel that a lot of time and money is being spent on something that will have very little practical use. Its similar to the TCAS In-Trail Climb that required so much testing, coordination and training and then is used maybe once every four or five months by the average controller. Programs that will actually help should be pushed. Primary, is reduced lateral separation throughout the ocean. Fifty miles maybe even 30 miles separation could be established. This would revolutionize our current flows and ultimately benefit the users as well as the controllers.
Controller B	RHSM in our present work environment (of one controller per sector) will not work. It is too time consuming and work intensive. Your may, in a very restricted situation, be able to use it to keep two aircraft at the same altitude for a brief period of time. 50 miles lateral separation would be a much great benefit to all concerned than the 50 miles longitudinal separation that we are testing.
Controller C	I'm concerned about the overall usefulness of RHSM. Certainly it will be another tool that we can use but I wonder about how often we will. We have intrail climbs and intrail descents that somebody thought was a great idea. Only occasionally do we use this because it is simply too time consuming to set up. The same will hold for RHSM. Its too time consuming and may be difficult to monitor. To me, more emphasis should be placed on more realistic separation standards that bring us to the technology currently used. My vote goes for 10 minutes longitudinal without Mach, 50 nm lateral separation, 1000 feet vertical at all altitudes and climb/descend through an altitude with seven minutes longitudinal separation. In addition, use vertical 10 minutes before to ten minutes after for head-on traffic. This is simple, safe and it moves traffic. What more could I ask for? One other comment I'd like to make is that I very much enjoyed working with you folks at the Tech Center. You're really trying to make this work and for that I give you lots of credit. You've put in many long, thankless and, at times, frustrating hours. I'm glad I was able to see how you do it and be a small part of the RHSM simulation project. I apologize that I couldn't attend the final two weeks of this project at the beginning of November but I hope that I'll be able to work with you again sometime.